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ABSTRACT

Equable climates with mild winters and summers are more likely to maintain snow or ice cover in high latitudes than extreme climates having colder winters and hotter summers. A simplified version of the Milankovitch cycles can be used to develop a model instructors can use in their classes to illustrate the orbital variations producing either equable or extreme climatic conditions. This model, suitable for high school or college use, uses sinusoidal, linear, and hand-drawn representations rather than sophisticated calculations and constructions to convey an understanding of how the earth's orbital variations affect climate. The model encourages students to think about the complex interactions of a few of the climate inputs and to experiment to match the known climate record. An appendix contains diagrams of the earth's rotation and its effects on climate. (Author/LP)

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ED241424

Title: Climatic Change and the Classroom: A Teaching Aid to Understanding

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Abstract: Equable climates with mild winters and summers are more likely to maintain snow/ice cover in high latitudes than extreme climates having colder winters and hotter summers. Using Milankovitch cycles, which recently have gained currency, a model for examining orbital variations producing either equable or extreme climatic conditions is developed. For pedagogic purposes, sophisticated calculations and mathematically precise construction of graphics are unnecessary. Sinusoidal, linear, or hand-drawn representations do equally well in conveying understanding of how the earth's orbital variations affect climate. The model facilitates student experimentation to match the known climate record, and through such experimentation comes understanding.

Suggested Level: Secondary and College

SO 013 480

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CLIMATIC CHANGE AND THE CLASSROOM:
A TEACHING AID TO UNDERSTANDING

The popular media have made many references to various aspects of climatic change. Each time a snowfall exceeds the record for a few locations or a new record minimum occurs, some reporter poses a question to the effect: "Is this the beginning of a new Ice Age?" Students who read or hear such reports eagerly ask, "Does this mean we're entering a new Ice Age?" The signal sent by such reported events is too weak for a clear reception, and we try to explain that no single temperature event nor single season of lower than normal temperatures can be interpreted as the onset of a climatic change. Many parameters enter the equation--changes in albedo and atmospheric absorption caused by dust and gases injected into the atmosphere by volcanoes, by agricultural and industrial activities, and by other natural and man-induced events.

We also mention the once-touted, then rejected, and now the once-again acclaimed Milankovitch cycles. We are cautious to point out that these and other factors, though not completely understood, are combined in complex ways which affect and alter global climatic conditons. We can use a simplistic model of the Milankovitch cycles, however, to help the student begin to see the intricate relationships involved in climatic change.

Certain basic assumptions are made and explained prior to using the simple model for what might be called Ice Age Cycles. For example, in the northern hemisphere, equable climates with mild winters and summers are more likely to maintain and extend snow and ice cover. Though not necessarily

warmer than freezing, warmer winter air temperatures of the northern hemisphere high and middle latitudes allow the transport of more water vapor and subsequently greater snowfall. The cooler temperatures of the northern hemisphere summer would allow the unmelted rim to extend farther southward, expanding the area under ice and snow. Each successive seasonal increase of snow-covered area would increase the global albedo resulting in a kind of positive feedback favoring glaciation.

For the northern hemisphere, then, orbital conditions which favor milder winters and summers enhance conditions for snow and ice build-up. Extreme climatic conditions in the northern hemisphere might result in snow cover advancing farther south in the winter, but the warmer summer temperatures would melt the snow cover farther northward during the summer. For the southern hemisphere, however, extreme seasonal variations may be necessary to increase the area under snow and ice. For example, extremely cold southern hemisphere winter temperatures would be necessary to chill the seawaters sufficiently to freeze and maintain the outward advance of Antarctic glaciation, and because the southern latitudes are largely ocean surface, extreme summer temperatures would be offset since much of the energy received would be used in the evaporation process rather than in heating.

So, with the above assumptions and neglecting other factors for simplicity's sake, we look at those orbital variations which produce equable, rather than extreme, climatic conditions for the northern hemisphere--i.e., mild winters and summers.

The so-called Milankovitch cycles involve three variations in the earth's orbit about the sun: 1) obliquity (or tilt) of the earth's axis; 2) precession of the equinoxes; and 3) eccentricity of the earth's orbit. (Figure 1)

OBLIQUITY

As the precession factor is often compared to the 'wobble' observed as a top spins, the obliquity variation is often referred to as a 'nodding' movement superimposed on the 'wobble.' (Figure 2) Obliquity varies from a minimum of 22.03 degrees to a maximum 24.5 degrees, a range of about two-and-one-half degrees. For the northern hemisphere, equable conditions occur when the tilt is at a minimum, and extreme climatic conditions occur during maximum tilt. The period of oscillation is given as 40 thousand years, sometimes 41 thousand years. More appropriately, the term 'period' should be "quasi-period" to acknowledge that the period is not as smooth and as regular as, for example, a sine curve.

Presently, the earth's axis has an obliquity of 23.44194 degrees (or about 23 degrees and 27 minutes) which is a decrease of 0.000129 degrees from 1982's measurement. We are, therefore, at a point in the obliquity cycle about halfway between maximum and minimum obliquity, and moving toward minimum.

A simple hand-drawn curve may be used to illustrate this part of the Milankovitch cycles. The upper portion of the curve represents the part of the cycle during which equable climatic conditions occur for the northern hemisphere; in other words, when conditions are favorable for glaciation--or, if one prefers, a possible ice age. The lower portion represents conditions unfavorable to glaciation. The "X" on the curve indicates approximately where we are currently in the obliquity cycle and the arrow indicates the direction of the trend.

PRECESSION

As mentioned earlier, precession is often referred to as being similar to the 'wobble' which occurs as a top spins. (Figure 3) This element has the

effect of causing the dates of our equinoxes, perihelion, and aphelion to "shift" (in a manner of speaking) around from the current calendar or seasonal dates. Presently, our near-sun position (that is, perihelion) occurs when the northern hemisphere is inclined away from the sun--about January the fourth. When aphelion occurs (about July fourth, which is the far-sun position)--the northern hemisphere is inclined toward the sun. The present situation enhances the equability of the northern hemisphere climates, offsetting, to a degree, the variation in heat received due to distance from the sun. As the equinoxes, perihelion, and aphelion "shift" over time, of course, the conditions change.

The period of this element of the Milankovitch Cycles is variously given as: 20 thousand, 21.7 thousand, and 25.7 thousand years. The period of 21.7 thousand years is termed "climatic precession" and is more applicable to variations in earth's seasonality.

According to H. H. Lamb, a noted British climatologist, the date of perihelion is occurring one day later every seventy years--in other words, perihelion is moving from a point which helps to produce equable climatic conditions toward a point which favors extreme climatic conditions. Using this bit of information we can place our current position as being slightly forward, or to the right, of the point of "equable" conditions and moving toward "extreme" conditions, as roughly indicated by the "X" and the arrow on the diagram.

ECCENTRICITY

The eccentricity parameter is a measure of the "shape" of the earth's orbit which varies over long periods from nearly circular to slightly more elliptical. (Figure 4) Eccentricity values range from 0.0005 to about 0.0607--the smaller the values, the more nearly circular the orbital ellipse.

When the eccentricity is small (nearly circular), there is little variation in seasonal heating gloablly (that is, equable conditions), but when the orbit has a greater eccentricity (more elliptical) a greater heating differential exists between seasons globally--producing extreme conditions.

The combined effects of eccentricity and precessional variation are intricately woven and are somewhat complex, occasionally adding to and then again, offsetting the other's production of equable or extreme climatic conditions. This fact is hereby acknowledged, but for simplicity of the exercise in this paper, each parameter is considered separately in terms of positive and negative attributes with respect to glaciation.

The average quasi-period of the eccentricity variable is about 95 thousand years (sometimes given as 100 thousand years). Currently the value is given as 0.0167 (nearly circular, thereby favoring equable climates) and perhaps moving toward more elliptical, as indicated on the figure.

STUDENT EXERCISE

To demonstrate how these factors may combine to influence climatic change, a simple hand-drawn curve could be constructed to an approximate scale representing the time intervals of each of the cycles. (Figure 5) For example, letting six inches represent 100 thousand years, then a 95 thousand year cycle is drawn with a 5.7 inch distance between peaks; similarly, the 21.7 thousand year precessional cycle may be represented with a 1.3 inch peak-to-peak curve; the 41 thousand year obliquity cycle with a 2.5 inch peak-to peak curve.

The upper portions of each curve represent times when conditions are favorable to equable northern hemisphere climates, or in other words, conditions which may lead to wide-spread glacial. The lower portions represent times when glaciation formation would be unlikely, or if glaciation formation did exist a retreat of glaciers may be initiated.

The student is assisted in ascertaining the point on each curve which likely represents where we are currently. (Figure 6) The curves are separated into strips and the students are asked to line up the points representing the current position. (Figure 7) The student is directed to search the arrangement for places (or times) where all of the curves indicate positive or negative conditions, or failing that, where two out of three are essentially either positive or negative. When the curves match up in a positive arrangement, ice build-up is favored. When the curves match negatively, glaciers, if occurring, might be forced into retreat, or at least begin to retreat. Figures 6 and 7 are samples of a student's work.

If the curves are transferred to a transparent medium, such as mylar or overhead transparency material, the strips may be laid one on top of the other to facilitate inspection for ice age conditions. (Figure 8)

Such a rough approximation will certainly not serve as the model for duplicating exactly the past climatic history nor to predict future events, but certain known past events may approximately coincide (if I may be permitted to use so loose a term) so that the student is rewarded by his efforts, giving him (or her) encouragement that he is "on to something," that his careful efforts have actually "pinpointed" a past event. And he thinks, "Hey, I may be able to predict something in the future."

For example, at Point A, two of the parameters are negative at about 10 thousand years before present, roughly coinciding with the end of the Pleistocene. Again, at Point B, a strong positive arrangement at approximately 25 thousand years before present, vary close to the deep glaciation of 18,000 years ago. At Point C, about 82 thousand years ago, the negative arrangement roughly identifies a period of non-glaciation which

coincides with a low ice volume suggested for that period by other research. And, finally, at Point D, a very neat (though perhaps coincidental) arrangement which could be said to indicate the deep-freeze glaciation of about 100 thousand years ago.

Granted, the exercise presented here is simplistic. It has many shortcomings, such as the lack of factor-weighting device, the neglect of the aperiodic components as well as the amplitude of the variations, the imprecision of locations where we are now, a summation procedure by which curves can be combined into one curve, and so on. This exercise was not developed to compete with the sophisticated equations and procedures of applied climatology professionals, but to give teachers and instructors of weather and climate a model to use in their classroom. As a model for encouraging students to think about the complex interactions of a few of the climate inputs, the exercise given here seems to work quite well.

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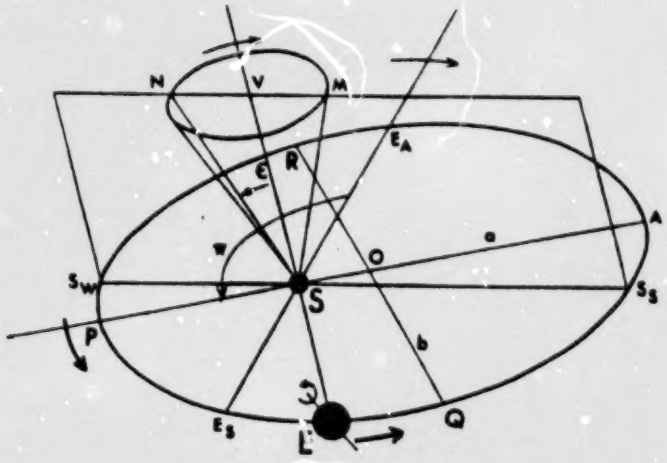


THE ELEMENTS OF THE EARTH'ORBIT AND VARIATIONS

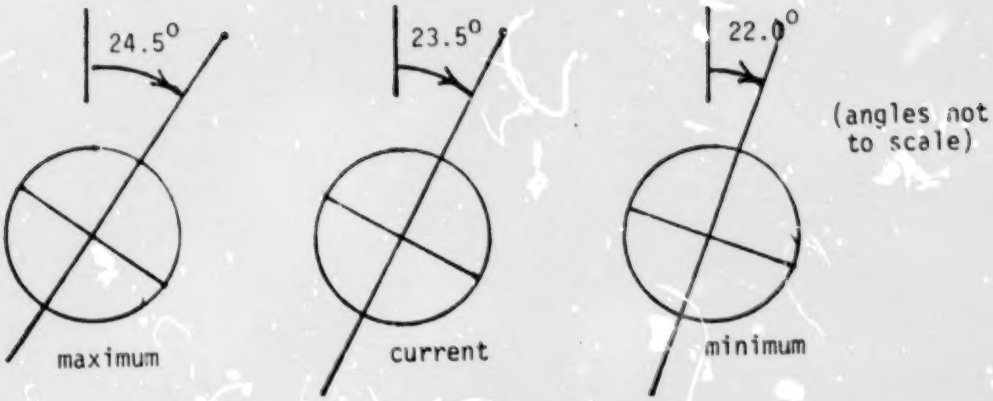
TO WHICH THEY ARE SUBJECT

(from H. H. Lamb,Climate: Past,

Present, and Future)

Figure 1

OBLIQUITY



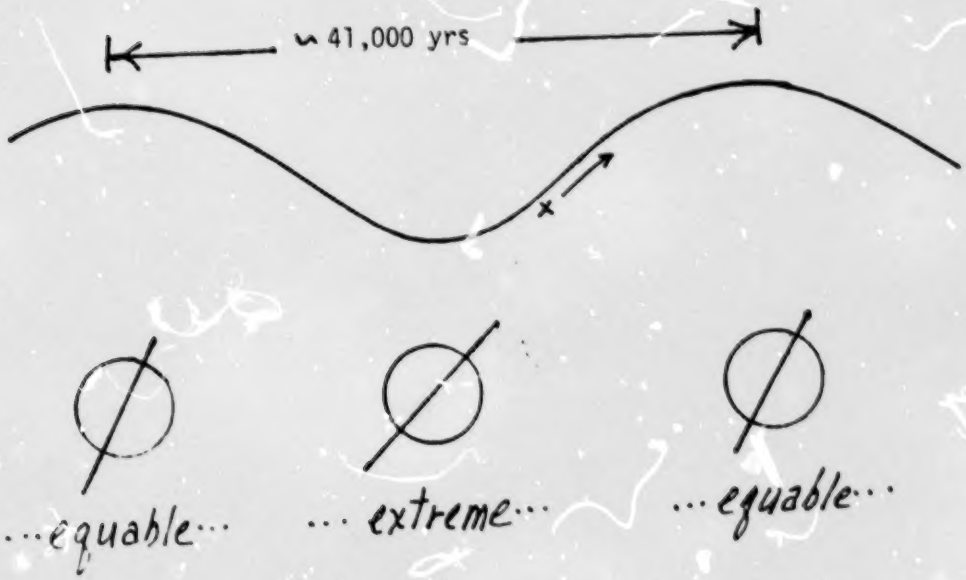
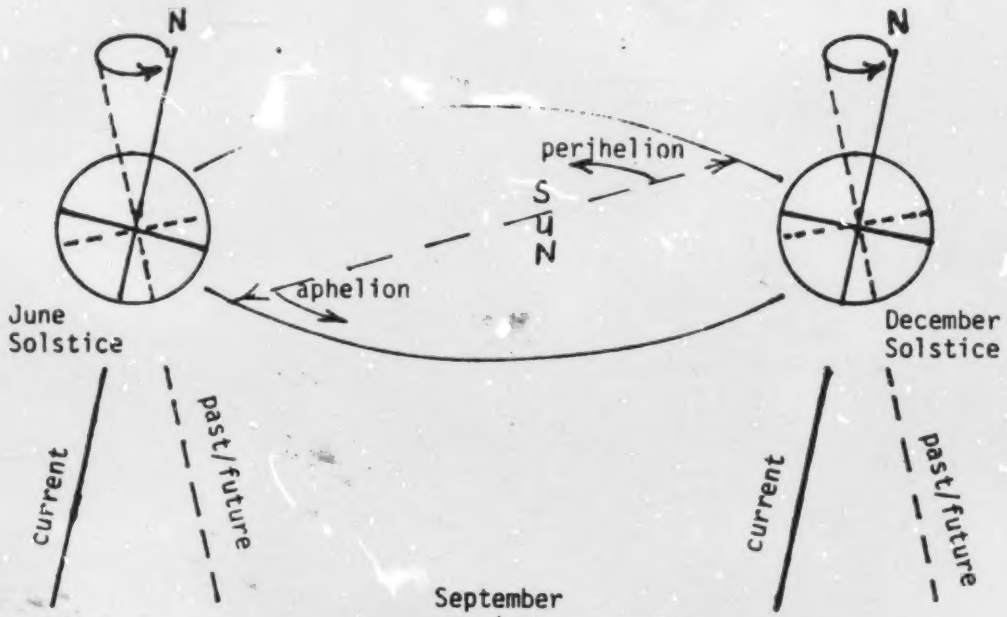
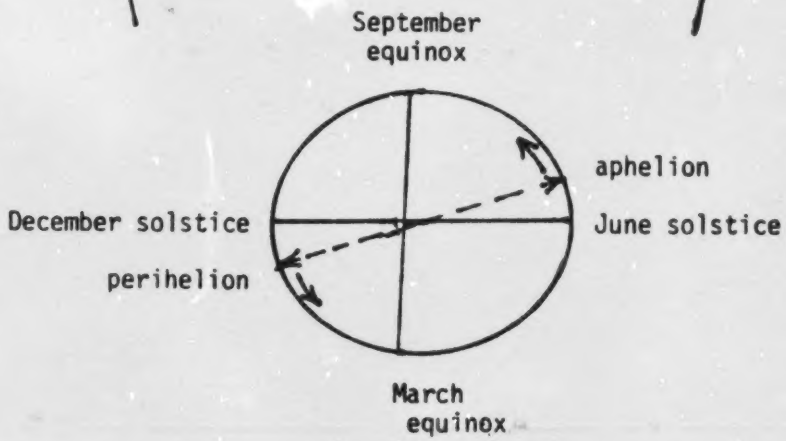


Figure 2

PRECESSION





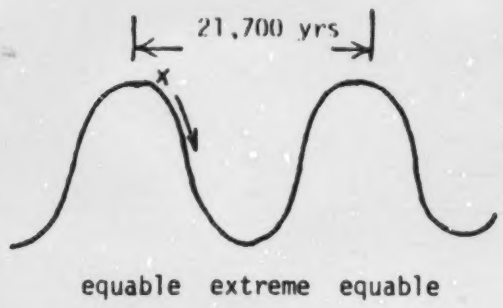
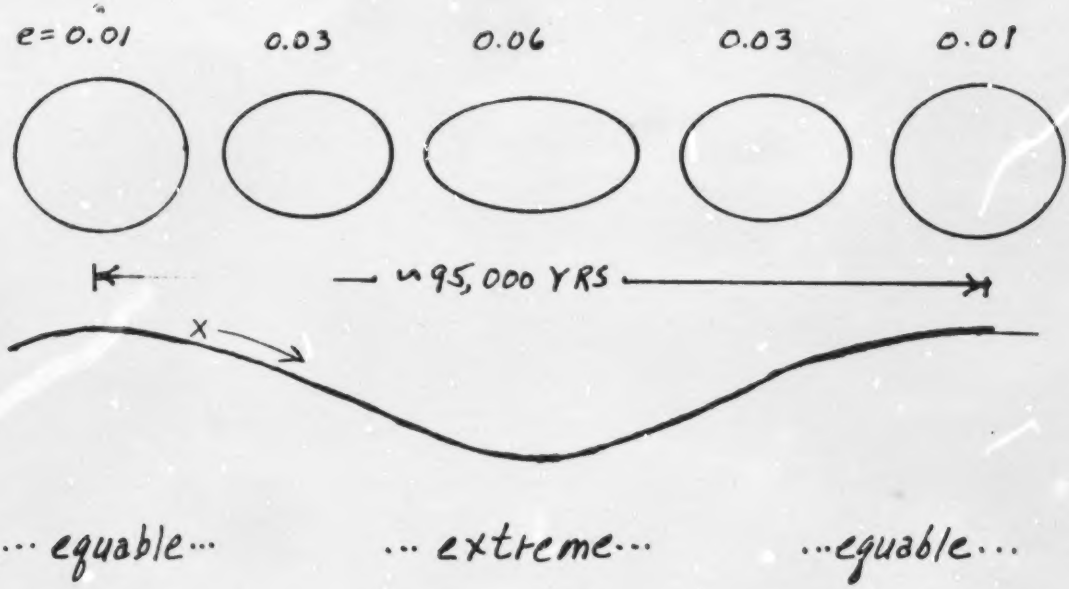


Figure 3



ECCENTRICITY OF EARTH'S ORBIT
(exaggerated ellipses)

Figure 4

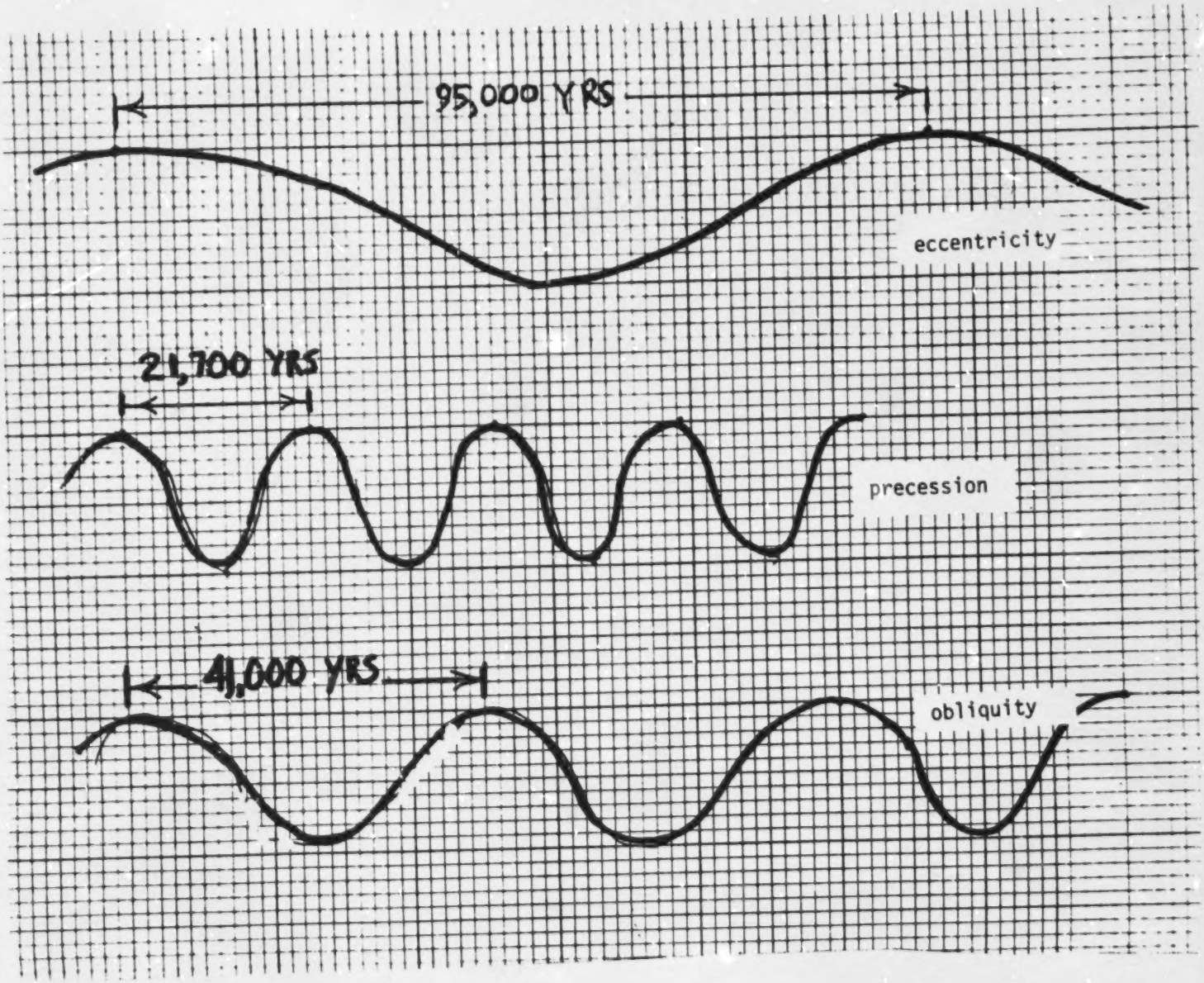
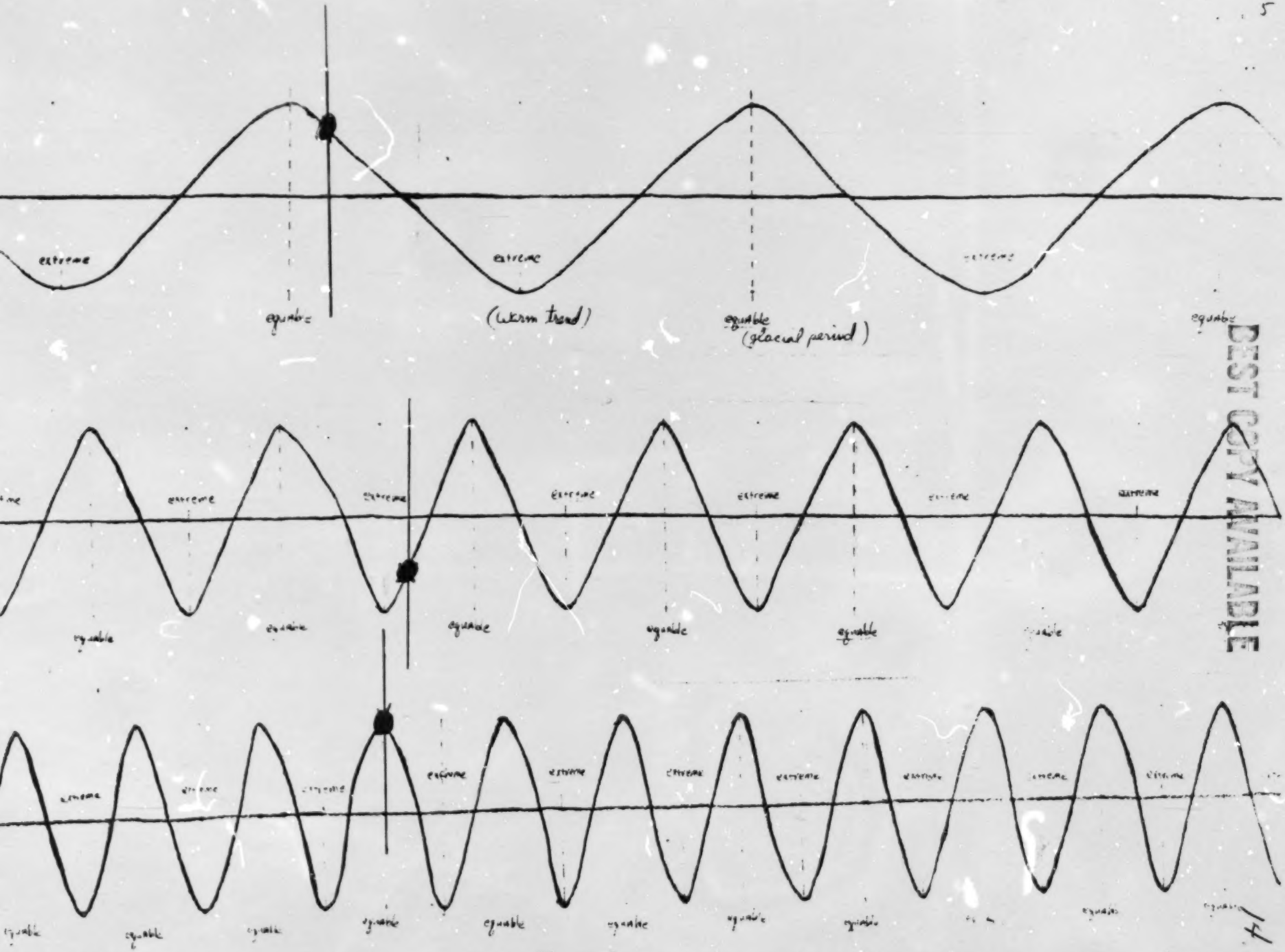
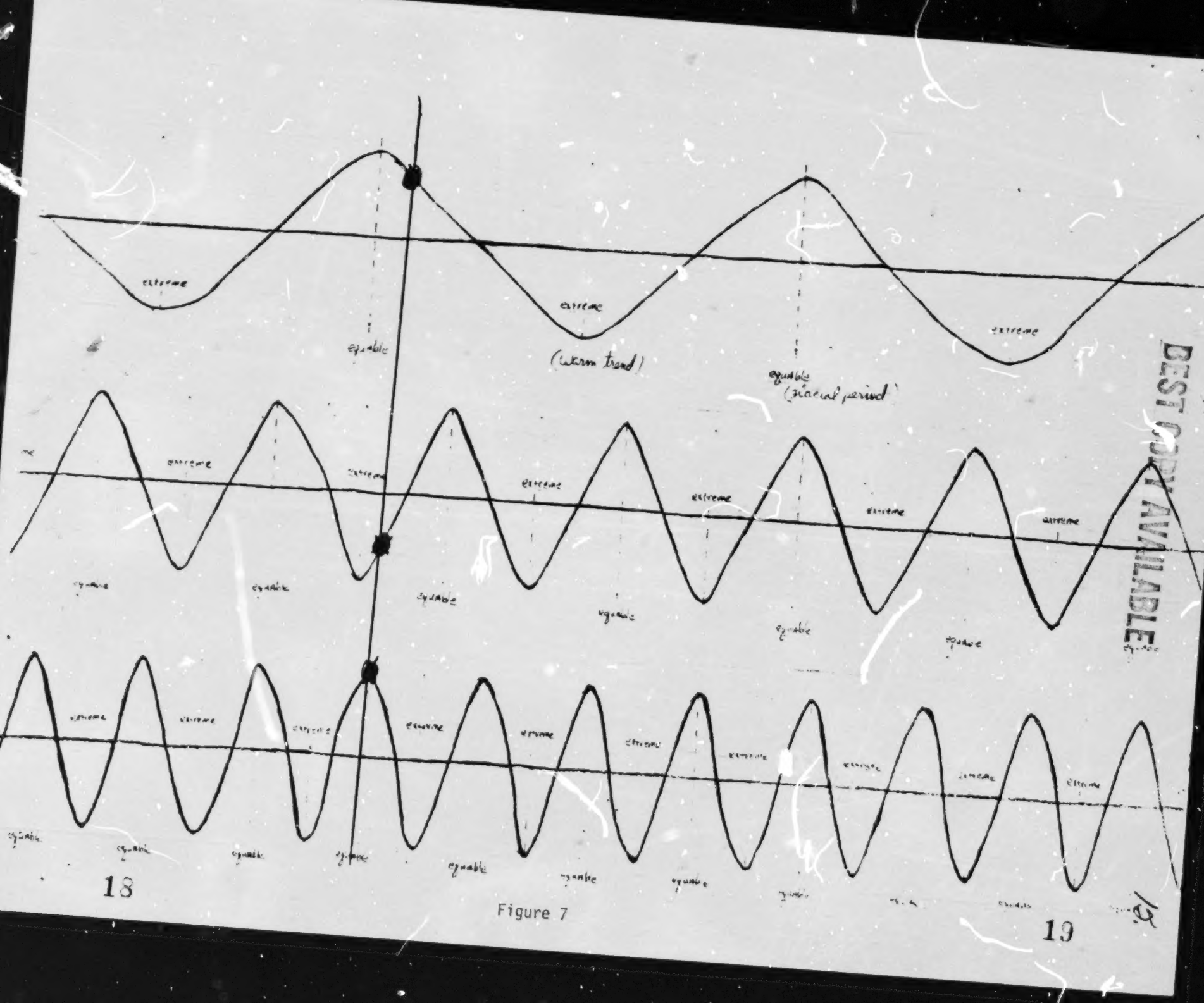

95,000 YRS
eccentricity
21,700 YRS
precession
41,000 YRS
obliquity

Figure 5


extreme
extreme
extreme
equable
(warm trend)
equable
(glacial period)
equable
equable
equable



BEST COPY AVAILABLE

Figure 7

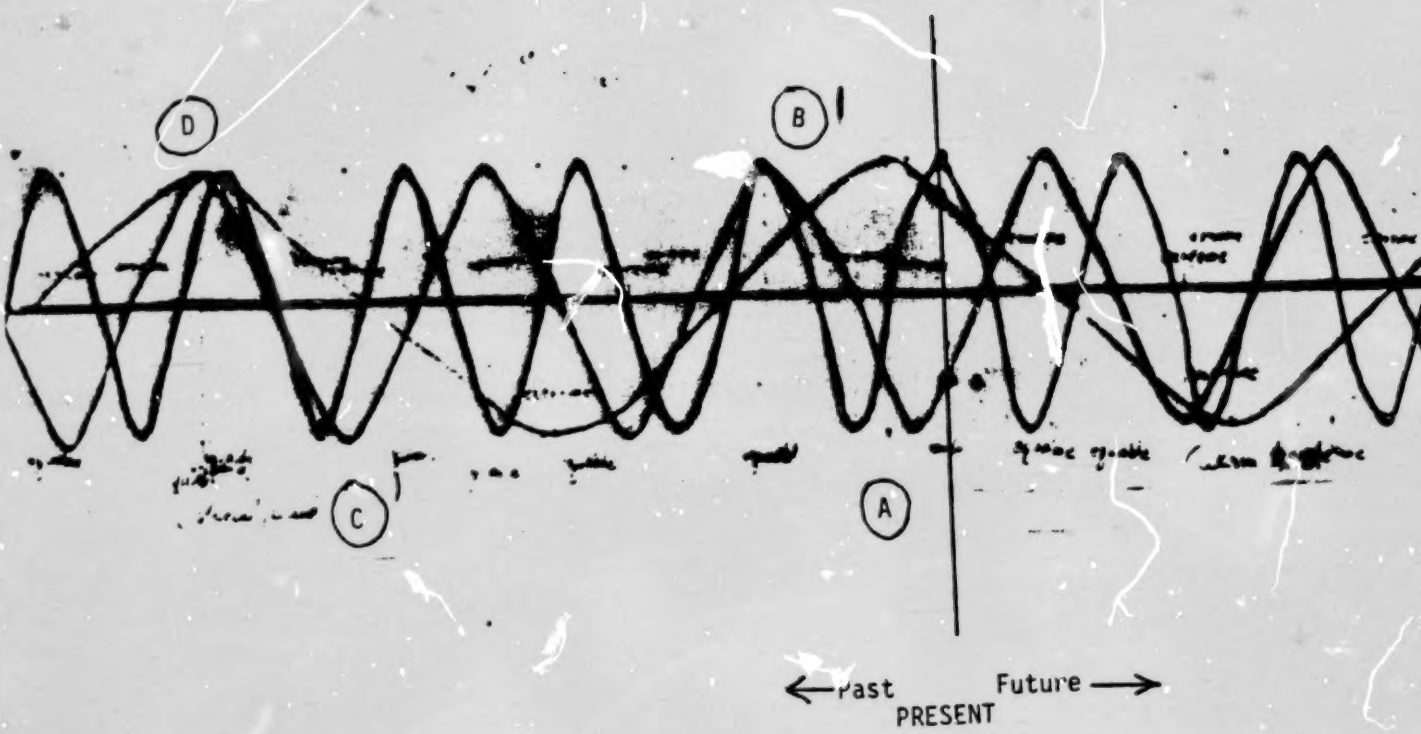


Figure 8